feeding by parasites in heavy infections can lead to complete destruction of the gonads and sterilization of the host (parasitic castration).

From a comparison of normal and infected digestive gland histology, the presence of rediae appears to reduce the number of gland acini. This reduction is probably due to active ingestion by redial stages, as reported by Porter *et al.* (1967), Reader (1971) and Robson & Williams (1971), though little direct histologic evidence for this pattern of redial feeding behavior is noted in *Cerithidea californica.* Perhaps mechanical pressures of developing parasites (James, 1965; Porter, 1970; Reader, 1971) or the presence of secretions or excretions of parasite origin (Cheng & Burton, 1965; Porter, 1970; Cheng *et al.*, 1973) also contribute to the decrease in acinar number. This is supported by the observation that heavy infections of *Spelotrema nicolli* and the strigeid, both utilizing sporocysts which do not feed by pharyngeal ingestion, also result in a reduction of digestive tubules. Yoshino (1974) has reported some light and electron microscopic evidence for cellular degeneration in deeper digestive gland tissues of *C. californica* infected with rediae of *Euhaplorchis californiensis.* This suggests that damage to the digestive gland acini may be through indirect as well as direct redial/tissue contact.

The occurrence of multiple trematode infections within a single host is well documented, especially for marine prosobranchs. Multiple infections have been reported by Hunter (1942) and Martin (1955) in *Cerithidea californica;* Vernberg *et al.* (1969) in the mudsnail, *Nassarius obsoletus;* and Robson & Williams (1970) in the periwinkle, *Littorina littorea* (Linnaeus, 1758). Both Martin (*op. cit.*) and Vernberg *et al.* (*op. cit.*) mention a nonconformity between the number of observed multiple infections, especially those involving echinostome species, and the number of infections expected by random combination. A similar situation also has been noted for multiple infections in freshwater gastropods (Cort *et al.*, 1937; Bourns, 1963; Lie, 1966). Multiple infections in *C. californica* from Goleta Slough do conform generally to expected frequencies, even when involving some species of echinostomes. The strigeid represents a notable exception, being observed only in double infections, never singly. This suggests that establishment of strigeid infections in *Cerithidea* may depend upon a prior infection of another trematode species which has in some manner altered the host's susceptibility to infection. A synergistic relationship such as this, however, can only be confirmed by controlled experimental infections in the laboratory.

In a recent review of mechanisms governing interspecific larval trematode interactions within a host, DeCoursey & Vernberg (1974) summarize the major kinds of interaction recognized in the literature today. They include: 1) complete coexistence, 2) preferential tissue selection, 3) longitudinal or radial displacement of one species, 4) cannibalism of one species on another (direct antagonism), 5) indirect antagonism, 6) hyperparasitism, and 7) alteration of the host's internal environment affecting its resistance. The occurrence of *Renicola buchanani* (mantle wall) with *Euhaplorchis californiensis* or the strigeid (visceral spiral) is possible since the selection of different tissue types allows for spacial separation between the species. However, when *E. californiensis* and the strigeid (both found primarily in the gonadal tissues) are present concurrently, *E. californiensis* (dominant species) will displace the strigeid, forcing it into the digestive gland, a locus of secondary preference (Figure *10*). One combination involving *E. californiensis* and the echinostome, *Parorchis acanthus*, was not observed during the present survey, though, according to random chance, this combination should have occurred about 3 times. However, during a recent study by the author of *Cerithidea's* cellular blood system, one such combination was encountered. Histologic examination reveals *Par-*

Explanation of Figures *8* to *11*

Figure *8*a: Cross-section of intestine (rectal region) in the mantle wall of an uninfected *Cerithidea californica.* Hematoxylin and eosin. approximately × 100

Figures *8*b, *8*c: Sporocysts of *Renicola buchanani* (toluidine blue) and rediae of *Catatropis johnstoni* (hematoxylin and eosin), respectively, infecting the mantle region of *Cerithidea.* × 120

Figure *9*: Infection of gonadal region by sporocysts of the strigeid (furcocercous cercaria). Toluidine blue. × 120

Figure *10*: Double infection of the gonadal and digestive gland regions by larval stages of *Euhaplorchis californiensis* and strigeid sporocysts. Toluidine blue. × 120

Figures *11*a, *11*b, *11*c: Double infection of the gonadal region by *Parorchis acanthus* rediae, and rediae and cercariae of *Euhaplorchis californiensis.* Toluidine blue. a) *P. acanthus* rediae occupying gonadal area of the anterior visceral spiral × 120. b) *E. californiensis* rediae and cercariae in the posterior region of the visceral spiral. × 120. c) *Parorchis* rediae with ingested cercariae of *Euhaplorchis.* × 300

DG – Digestive Gland Tubules
CE – Cercarial Stage(s)
IN – Intestine
MA – Mantle Tissues
RE – Redial Stage(s)
SP - Sporocyst Stage(s)

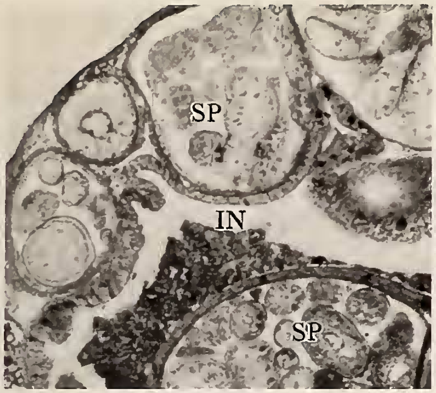

Figure *8*b

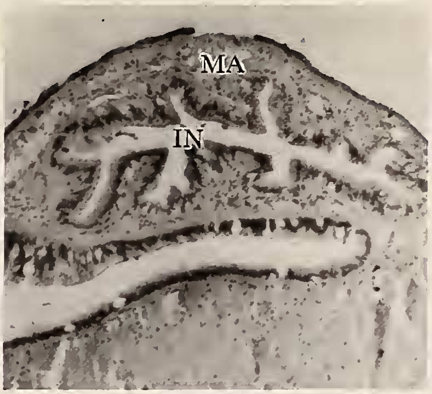

Figure *8*a

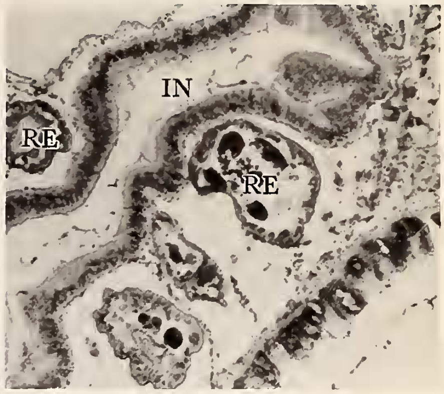

Figure *8*c

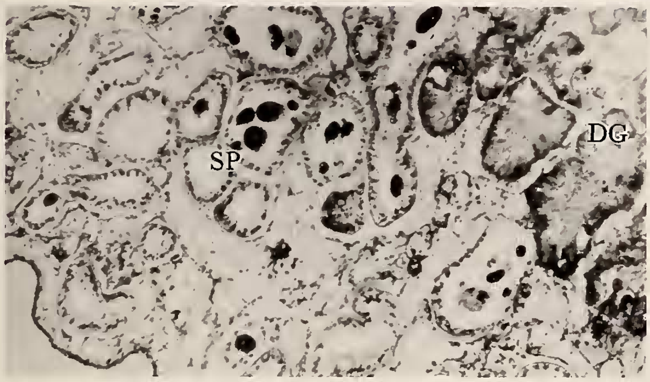

Figure *9*

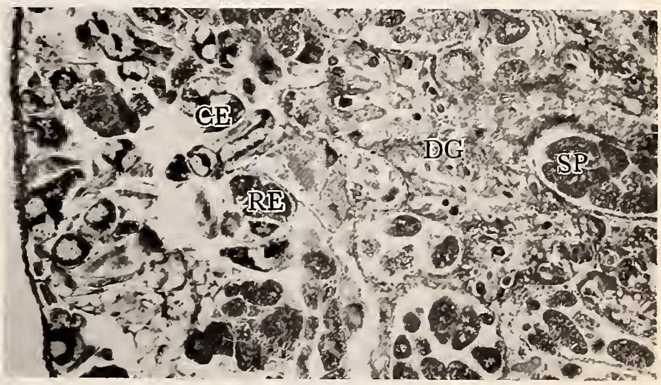

Figure *10*

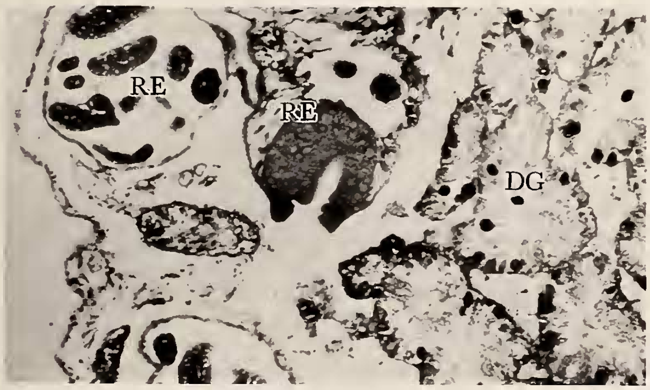

Figure *11*a

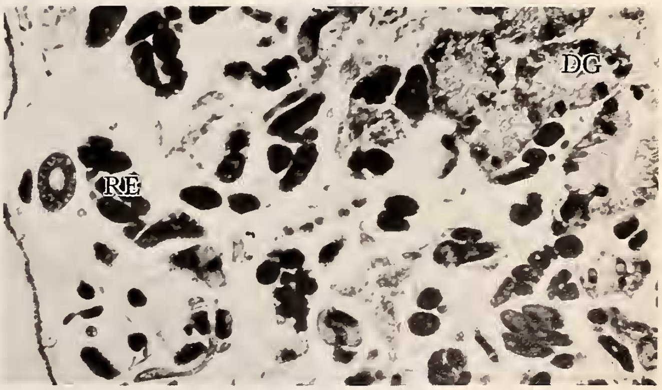

Figure *11*b

Figure *11*c

orchis to be strongly antagonistic towards *E. californiensis*, laterally displacing, by active predation, the heterophyid in a posterior direction in the host (Figures *11*a, *11*b, *11*c). These observations lend support to the negative inference that double infections involving *Parorchis* rediae are rare due to their antagonistic behavior towards other trematode species. A single observation is not, however, very reliable and confirmation of this kind of interaction must await double infection experiments on *Cerithidea,* similar to those being performed on freshwater planorbids (reviewed by Lim & Heyneman, 1972).

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Literature Cited

Adams, Joel E. & Walter E. Martin
1963. Life cycle of *Himasthla rhigedana* Dietz, 1909 (Trematoda: Echinostomatidae). Trans. Amer. Microsc. Soc. 82: 1 - 6

Bourns, T. K. R.
1963. Larval trematodes parasitizing *Lymnaea stagnalis appressa* Say in Ontaria with emphasis on multiple infections. Canad. Journ. Zool. 41: 937 - 941

Cheng, Thomas Clemant & Richard W. Burton
1965. Relationships between *Bucephalus* sp. and *Crassostrea virginica*: Histopathology and sites of infection. Chesapeake Sci. 6: 3 - 16

Cheng, Thomas Clemant, John T. Sullivan & Kevin R. Harris
1973. Parasitic castration of the marine prosobranch gastropod *Nassarius obsoletus* by sporocysts of *Zoogonus rubellus* (Trematoda): Histopathology. Journ. Invert. Pathol. 21: 183 - 190

Cort, William W., Donald B. McMullen & Sterling Brackett
1937. Ecological studies on the cercariae in *Stagnicola emarginata* (Sowerby) in the Douglas Lake region. Journ. Parasit. 23: 504 - 532

DeCoursey, Patricia J. & Winona B. Vernberg
1974. Double infections of larval trematodes: competitive interactions. *In*: Symbiosis in the Sea (W. B. Vernberg, ed.); xvi+276 pp.; illust. Univ. So. Carolina Press, Columbia, S. C.

Hunter, Wanda S.
1942. Studies on cercariae of the common mud-flat snail, *Cerithidea californica*. Ph. D. thesis, Univ. Calif. Los Angeles; 129 pp.; 51 text figs.; 5 charts; 12 tables

James, Brian Lloyd
1965. The effects of parasitism by larval Digenea on the digestive gland of the intertidal prosobranch, *Littorina saxatilis* (Olivi) subsp. *tenebrosa* (Montagu). Parasitology 55: 93 - 115

Jurek, Ronald M. & Howard R. Leach
1971. California shore bird survey, 1969-1970. Spec. Wildl. Reprt. Calif. Dept. Fish & Game: 91 pp.; illust.

Lie, Kian J.
1966. Antagonistic interaction between *Schistosoma mansoni* sporocysts and echinostome rediae in the snail *Australorbis glabratus*. Nature (London) 211: 1213 - 1215

Lim, Hok-kan & Donald Heyneman
1972. Intramolluscan inter-trematode antagonism: a review of factors influencing the host-parasite system and its possible role in biological control. *In*: Advances in Parasitology (B. Dawes, ed.); vol. 10; 412 pp.; illust. Academic Press, London & New York

Martin, Walter E.
1950a. *Euhaplorchis californiensis* n. g., n. sp., Heterophyidae, Trematoda, with notes on its life-cycle. Trans. Amer. Microscop. Soc. 69: 194 - 209
1950b. *Parastictodora hancocki* n. gen., n. sp. (Trematoda: Heterophyidae), with observations on its life cycle. Journ. Parasit. 36: 360 - 370
1950c. *Phocitremoides ovale* n. gen., n. sp. (Trematoda: Opisthorchidae), with observations on its life cycle. Journ. Parasit. 36: 552 - 558
1951. *Pygidiopsoides spindalis* n. gen., n. sp. (Heterophyidae; Trematoda), and its second intermediate host. Journ. Parasit. 37: 297 - 300
1955. Seasonal infections of the snail, *Cerithidea californica* Haldeman, with larval trematodes. *In*: Essays in the Natural Sciences; Alan Hancock Foundaton; 335 pp.; illust.; Univ. So. Calif. Press, Los Angeles
1956. The life cycle of *Catatropis johnstoni* n. sp. (Trematoda: Notocotylidae). Trans. Amer. Microsc. Soc. 75: 117 - 128

Martin, Walter E. & V. L. Gregory
1961. Life cycle of *Acanthoparyphium spinulosum* Johnston, 1917 (Echinostomatidae: Trematoda). Journ. Parasit. 47: 777 - 782

Martin, Walter B. & V. L. Gregory
1951. *Cercaria buchanani* n. sp., an aggregating marine trematode. Trans. Amer. Microsc. Soc. 70: 359 - 362

Martin, Walter E. & David F. Steele
1970. *Ascocotyle sexidigita* sp. n. (Trematoda: Heterophyidae) with notes on its life cycle. Proc. Helminth. Soc. Wash. 37: 101 - 104

Maxon, Marion G. & Willis E. Pequegnat
1949. Cercariae from Upper Newport Bay. Journ. Entomol. Zool. 4: 30 - 50

Porter, Clarence A.
1970. The effects of parasitism by the trematode *Plagioporus virens* on the digestive gland of its snail host, *Flumenicola virens*. Proc. Helminth. Soc. Wash. 37: 39 - 44

Porter, Clarence A., Ivan Pratt & Alfred Owczarzak
1967. Histopathological and histochemical effects of the trematode *Nanophyetus salmincola* (Chapin) on the hepatopancreas of its snail host, *Oxytrema siliqua* (Gould). Trans. Amer. Microsc. Soc. 86: 232 - 239

Reader, Trevor A. J.
1971. The pathological effects of sporocysts, rediae and metacercariae on the digestive gland of *Bithynia tentaculata* (Mollusca: Gastropoda). Parasitology 63: 483 - 489

Robson, W. M. & I. C. Williams
1970. Relationships of some species of Digenea with the marine prosobranch *Littorina littorea* (L.). I. The occurrence of larval Digenea in *L. littorea* on the North Yorkshire coast. Journ. Helminth. 44: 153 - 168
1971. Relationships of some species of Digenea with the marine prosobranch *Littorina littorea* (L.). II. The effect of larval Digenea on the reproductive biology of *L. littorea*. Journ. Helminth. 45: 145 - 159

Vernberg, Winona B., F. John Vernberg & Fred W. Beckerdite, Jr.
1969. Larval trematodes: Double infections in the common mud-flat snail. Science 164: 1287 - 1288

Yoshino, Timothy P.
1972. Helminth parasitism in the Pacific killifish, *Fundulus parvipinnis*, from southern California. Journ. Parasitol. 58: 635 - 636
1974. Some fine structural observations on the histopathologic effects of larval Digenea on gastropod digestive gland acinar cells. Proc. Third Internat. Congress Parasitol. 3: 1704 - 1705 (abstract only)